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Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and David E. Knapp, Editors

Volume 23

BOREAS HYD-3 Subcanopy Meteorological Measurements

J.P. Hardy and R.E. Davis

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2000

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Space Administration

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BOREAS HYD-3 Subcanopy Meteorological Measurements

Janet P. Hardy, Robert E. Davis

Summary

The BOREAS HYD-3 team collected several data sets related to the hydrology of forested areas. This data set includes measurements of wind speed and direction; air temperature; relative humidity; and canopy, trunk, and snow surface temperatures within three forest types. The data were collected in the SSA-OJP (1994) and SSA-OBS and SSA-OA (1996). Measurements were taken for 3 days in 1994 and 4 days at each site in 1996. These measurements were intended to be short term to allow the relationship between subcanopy measurements and those collected above the forest canopy to be determined. The subcanopy estimates of wind speed were used in a snow melt model to help predict the timing of snow ablation. The data are available in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS HYD-03 Subcanopy Meteorological Measurements

1.2 Data Set Introduction

This data set includes measurements of wind speed and direction within one aspen and two conifer forests. The data were collected in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) Old Jack Pine (OJP) (1994) and the SSA-Old Black Spruce (OBS) and SSA-Old Aspen (OA) (1996). Measurements were taken for only 3 days in 1994 and 4 days at each site in 1996. An RM Young wind monitor, a Vaisala temperature and relative humidity (temp/RH) probe, and infrared thermometers were used to measure canopy, trunk, and snow surface temperatures. The wind monitor and temp/RH probe were mounted 2 meters above the snow surface, and a Campbell Scientific CR10 data logger was used for all data collection.

1.3 Objective/Purpose

This study was undertaken to predict spatial distributions of energy transfer and snow properties important to the hydrology, remote sensing signatures, and transmissivity of gases through the snow and their relation to forests in boreal ecosystems. The purpose of these measurements was to allow the relationship between subcanopy measurements and those collected above the forest canopy to be determined. Once they were determined, the above-canopy measurements were modified to estimate the subcanopy measurements. The subcanopy estimates of wind speed were used in the snow melt model to help predict the timing of snow ablation.

1.4 Summary of Parameters

Parameters measured with respect to this documentation are canopy wind speed and direction, air temperature, relative humidity, stem temperature, and snow surface temperature.

1.5 Discussion

During the Focused Field Campaign-Winter (FFC-W) in 1994 and 1996, meteorological parameters were measured at 2 m height in SSA-OJP (1994) and SSA-OBS and OA (1996). The data were collected for only 3 days (1994) or 4 days (1996) and are intended for comparison with above-canopy meteorological data. The data are averages of several measurements over a 10-min. (1994) and 1-min. (1996) interval. An RM Young wind monitor, a Vaisala temp/RH probe mounted 2 meters above the snow surface, and a Campbell Scientific CR10 data logger were used for data collection. Infrared thermometers were aimed at tree canopies, trunks, and the snow surface to provide measurements. The sensors and the data logger system are among the best available. Because of the nature of the forest canopy, wind speeds were VERY low, and in many cases below the threshold value of the sensor (1.0 m/s). For this reason, the data are somewhat questionable as to the absolute magnitude of the wind, but provide good relative information as to the timing and magnitude of wind events. The wind direction data are believed to be as accurate as the manufacturer's specifications.

1.6 Related Data Sets

BOREAS TF-02 SSA-OA Tower Flux Data
BOREAS TF-01 SSA-OA Tower Flux Data
BOREAS TF-05 SSA-OJP Tower Flux Data
BOREAS TF-09 SSA-OBS Tower Flux Data
BOREAS HYD-03 Subcanopy Incoming Solar Radiation Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Robert E. Davis, Research Physical Scientist
U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)

2.2 Title of Investigation

Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems

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3. Theory of Measurements

The meteorological data were collected to investigate the effect of forest structure on the within-canopy winds, temperatures, and humidity. Data were compared with those collected from BOREAS flux towers at heights above the canopy to assist in developing a relationship between subcanopy and above-canopy winds in species of the boreal forest. This understanding is essential in modeling snow ablation in the forest.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

All data were collected during winter campaigns; therefore, the instruments were subjected to cold temperatures. Days were relatively clear and cold, and forest winds were light during the collection period. Cold temperatures would not affect the sensors nor the data quality, but low wind speeds (below the 1.0 m/s threshold) affect the quality of wind data.

4.1.2 Source/Platform

2-meter tower in forest.

4.1.3 Source/Platform Mission Objectives

The objective was to measure within-canopy winds, temperature, and humidity.

4.1.4 Key Variables

Within Canopy:

Wind speed and wind direction, air temperature, relative humidity, trunk and snow surface temperature.

4.1.5 Principles of Operation

Wind Monitor: The wind monitor measures horizontal wind speed and direction. Propeller rotation produces an AC signal with frequency proportional to wind speed. The AC signal is monitored and data are processed by a Campbell data logger. Wind direction is measured by applying constant voltage to a potentiometer; the output signal is an analog voltage directly proportional to azimuth angle.

Temp/RH Probe: Sensors within the probe measure the air temperature and relative humidity according to specifications discussed below.

Infrared Thermometers: An infrared thermometer measures radiant energy. Temperature readings are taken with an infrared thermometer by aiming the infrared temperature transducer at the desired object. The infrared thermometers used in this study have fields-of-view (FOV) of 15° and 4°. It was important in orienting the temperature sensor that the entire FOV was filled with the desired object.

Infrared Radiometers: The Eppley Precision Infrared Radiometer (PIR) (pyrgeometer) measures incoming longwave radiation of wavelengths between 4 μm and 50 μm. This instrument is believed to be the most accurate radiometer produced commercially for the measurement of longwave radiation. The pyrgeometer measures the exchange of radiation between a horizontal blackened surface (i.e., the detector) and the target viewed (i.e., sky or ground). The signal is monitored and data are processed on a Campbell Scientific data logger (CR10).

4.1.6 Sensor/Instrument Measurement Geometry

Wind Monitor: This sensor was located on top of a tower, 2 meters above the snow surface. The sensor was oriented to true south in 1994 during installation, except in 1996, when the sensor was oriented to magnetic south.

Temp/RH Probe: This sensor with radiation shield was mounted on the same tower approximately 2 m above the snow surface.

Infrared Thermometer: The infrared thermometers used to measure canopy and trunk temperatures were mounted on tripods, approximately 1 m above the snow surface, and the sensor was pointed at the west or east side of the tree trunk. For infrared thermometers pointing at the canopy, care was taken to find a thick part of the canopy and to avoid measuring any background. The radiometer used for snow surface temperature measurements was similarly mounted on a tripod and aimed at the snow surface.

Infrared Radiometers (pyrgeometers): Sensors were located on the snow surface using either a foam block (1994) or the radiometer case (1996) for support on the snow surface. Sensors were leveled daily using the bubble level mounted on the radiometer base.

4.1.7 Manufacturer of Sensor/Instrument

Wind Monitor:
Manufacturer: R.M. Young Company
Distributor: Campbell Scientific Inc.
815 W. 1800 N.
Logan, Utah 84321-1784
(801) 753-2342

Vaisala Temp/RH Probe, Model HMP35C:
Manufacturer: Vaisala, Inc., Woburn, MA
Distributor: Campbell Scientific, Inc.
815 W. 1800 N.
Logan, UT 84321-1784
(801) 753-2342

Everest Series 4000 Infrared Temperature Transducer (low temperature model)
Manufacturer: Everest Interscience, Inc.
Everest Interscience, Inc.
1120 S. Raymond
Fullerton, CA 92631
(800) 422-4342

Eppley Precision Infrared Radiometer (pyrgeometer)
Manufacturer: Eppley Laboratory, Inc.
12 Sheffield Ave.
Newport, RI 02840
(401) 847-1020

4.2 Calibration

- Wind Monitor: The sensor was oriented to true south during installation, except in 1996 when the sensor was oriented to magnetic south. A Brunton compass was used in the orientation of the sensor. This sensor is better oriented to the south because of a 5° "dead zone" between 355° and 360°.
- Temp/RH probe: Probes are calibrated to specifications of +/- 3% RH. Recalibration is performed at room temperature at 20%, 50%, and 85% RH.
- Infrared Thermometers: Infrared temperature transducers were calibrated by Everest upon purchase. Laboratory tests were conducted periodically for comparison of sensors and to provide confidence in the data.
- Infrared Radiometers (pyrgeometers): All pyranometers were new in 1994 and were therefore factory calibrated, with reference to Eppley primary standards, just prior to deployment in the field in 1994.

4.2.1 Specifications

Wind Monitor: The RM Young sensor has a 5°, wind direction, "dead zone" between 355° and 360°.

Temp/RH Probe: The probe is used only with a white radiation shield obtained from the distributor.

Infrared Thermometers:
Spectral pass-band = 8 mm to 14 mm.
emmissivity preset at factory at 0.98.
FOV = 4° and 15°.
Operating distance = 0.2 m to 1,000 ft focus.
Optical configuration = 35-mm precision corrected refractive optics.

Infrared Radiometers (pyrgeometers):
Sensitivity = 4 μVolts per Watt per m^2
Receiver: circular 1 cm^2 in area.
Linearity = +/- 1%, 0 to 700 Watts per m^2
Cosine response = better than 5% from normalization, insignificant for a diffuse source.

4.2.1.1 Tolerance

Wind Speed:
Accuracy = +/- 0.3 m/s.
Wind speed threshold sensitivity = 1.0 m/s
(the wind speed data are not accurate below 1.0 m/s).
Wind Direction:
Accuracy = +/- 3.0° (<1%).

Temp/RH probe:
RH range = 0-100%.
Temperature range: -35 °C to 50 °C.
Accuracy at temperatures between -24°C and 48°C = <+/-0.1°C.
Accuracy at temperature of -40°C = +/-0.5°C.

Infrared thermometers:
Temperature range = -25 °C to 75 °C.
Accuracy = +/-0.5 °C.
Resolution = +/- 0.1 °C.

Infrared radiometers:
Temperature dependance = +/- 2%, -20 °C to 40 °C.

4.2.2 Frequency of Calibration

- Wind Monitor: The RM Young wind sensor was fully calibrated when purchased on 19-Jan-1994 and has not been recalibrated since purchase. The RM Young manual provides details on calibrating the sensor.
- Temp/RH Probe: On a regular basis and prior to field use, several Vaisala Temp/RH probes are run adjacent to each other and concurrently to compare precision with other sensors. Probes that appear to be imprecise are either returned to the manufacturer for recalibration, or retired. Only probes with a high degree of precision are used in the field. This instrument was bought on 30-Jun-1994.
- Infrared Thermometers: Factory calibrated upon initial purchase.
  - Infrared thermometer #1: bought in 1994.
  - Infrared thermometer #2: bought in 1994.
  - Infrared thermometer #3: bought in 1991, recalibrated 1992.
  - Infrared thermometer #3 was returned to manufacturer 1 year after purchase to improve its cold weather handling and recalibrated, since it is an older model. Prior to field use we conducted laboratory tests using 0 °C ice baths to provide confidence in instrument.
- Infrared Radiometers (pyrgeometers): The manufacturer of the pyranometers recommends calibration after a cumulative use of 2 years. These radiometers were new at the beginning of the FFC-W 1994 and therefore are well within calibration. Because they have been used for only ~20 days per year and stored in their dark case when not in use, the calibration should be valid for several years at the current rate of usage.

4.2.3 Other Calibration Information

Available from the manufacturer.

5. Data Acquisition Methods

All sensors were installed according to manufacturer procedures. Data were recorded on a Campbell Scientific data logger. The data logger was programmed to measure parameters every minute and output 10-minute averages (1994) and measure parameters every second and output 1-minute averages (1996).

6. Observations

6.1 Data Notes
None given.

6.2 Field Notes
Wind direction oriented to true south in 1994. Wind direction oriented to magnetic south in 1996.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

Site	Year	Longitude	Latitude
SSA-OJP	1994	104.69203W	53.91634N
SSA-OBS	1996	105.11779W	53.98718N
SSA-OA	1996	106.19779W	53.6289N

All measurements were made within 50 meters of flux tower sites.

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
Point data, 2-meter height in forest.

7.1.4 Projection
All latitude/longitude locations are given in the North American Datum of 1983 (NAD83).

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
FFC-W 1994: 06-Feb-1994 - 10-Feb-1994

SSA-OJP: 06-Feb-1994 - 10-Feb-1994
SSA-OBS: 28-Feb-1996 - 03-Mar-1996
SSA-OA: 04-Mar-1996 - 08-Mar-1996

7.2.2 Temporal Coverage Map
SSA-OJP: 06-Feb-1994 - 10-Feb-1994
SSA-OBS: 28-Feb-1996 - 03-Mar-1996
SSA-OA: 04-Mar-1996 - 08-Mar-1996

7.2.3 Temporal Resolution
10-minute averages (1994), 1-minute averages (1996)

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Column Name
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
MEAN_DOWN_THERMAL_RAD_1
MEAN_DOWN_THERMAL_RAD_2
MEAN_WIND_SPEED_2M
MEAN_WIND_SPEED_VECTOR_MAG_2M
MEAN_WIND_VECTOR_DIR_2M
SDEV_WIND_DIR_2M
CANOPY_TEMP_1
CANOPY_TEMP_2
TRUNK_TEMP_1
TRUNK_TEMP_2
AIR_TEMP_2M
SNOW_SURF_TEMP
REL_HUM_2M
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
MEAN_DOWN_THERMAL_RAD_1	The mean thermal radiation to the surface.
MEAN_DOWN_THERMAL_RAD_2	The mean thermal radiation to the surface.
MEAN_WIND_SPEED_2M	The mean wind speed that was measured at 2 meters above the ground.
MEAN_WIND_SPEED_VECTOR_MAG_2M	The mean wind vector magnitude at 2 meters above the ground.

MEAN_WIND_VECTOR_DIR_2M	The mean wind direction at 2 meters above the ground.
SDEV_WIND_DIR_2M	The standard deviation of the wind direction at 2 meters above the ground.
CANOPY_TEMP_1	The temperature of the canopy from sensor 1.
CANOPY_TEMP_2	The temperature of the canopy from sensor 2.
TRUNK_TEMP_1	The temperature of tree trunk 1 at the site.
TRUNK_TEMP_2	The temperature of tree trunk 2 at the site.
AIR_TEMP_2M	The air temperature at 2 meters above the ground.
SNOW_SURF_TEMP	The temperature of the snow surface.
REL_HUM_2M	The relative humidity at 2 meters above ground.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
MEAN_DOWN_THERMAL_RAD_1	[Watts][meter^-2]
MEAN_DOWN_THERMAL_RAD_2	[Watts][meter^-2]
MEAN_WIND_SPEED_2M	[meters][second^-1]
MEAN_WIND_SPEED_VECTOR_MAG	[meters][second^-1]
MEAN_WIND_VECTOR_DIR_2M	[degrees]
SDEV_WIND_DIR_2M	[degrees]
CANOPY_TEMP_1	[degrees Celsius]
CANOPY_TEMP_2	[degrees Celsius]
TRUNK_TEMP_1	[degrees Celsius]
TRUNK_TEMP_2	[degrees Celsius]
AIR_TEMP_2M	[degrees Celsius]
SNOW_SURF_TEMP	[degrees Celsius]
REL_HUM_2M	[percent]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Supplied by Investigator]
TIME_OBS	[Supplied by Investigator]
MEAN_DOWN_THERMAL_RAD_1	[Supplied by Investigator]
MEAN_DOWN_THERMAL_RAD_2	[Supplied by Investigator]

MEAN_WIND_SPEED_2M	[Supplied by Investigator]
MEAN_WIND_SPEED_VECTOR_MAG	[Supplied by Investigator]
MEAN_WIND_VECTOR_DIR_2M	[Supplied by Investigator]
SDEV_WIND_DIR_2M	[Supplied by Investigator]
CANOPY_TEMP_1	[Supplied by Investigator]
CANOPY_TEMP_2	[Supplied by Investigator]
TRUNK_TEMP_1	[Supplied by Investigator]
TRUNK_TEMP_2	[Supplied by Investigator]
AIR_TEMP_2M	[Supplied by Investigator]
SNOW_SURF_TEMP	[Supplied by Investigator]
REL_HUM_2M	[Supplied by Investigator]
CRTFCN_CODE	[Assigned by BORIS]
REVISION_DATE	[Assigned by BORIS]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9OA-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	HYD03-SCM01	HYD03-SCM01	None	None	None	None
DATE_OBS	06-FEB-94	08-MAR-96	None	None	None	None
TIME_OBS	0	2359	None	None	None	None
MEAN_DOWN_THERMAL_RAD_1	176.1	264.5	-999	None	None	Blank
MEAN_DOWN_THERMAL_RAD_2	176.2	315.1	-999	None	None	Blank
MEAN_WIND_SPEED_2M	0	1.766	-999	None	None	Blank
MEAN_WIND_SPEED_VECTOR_MAG_2M	0	1.581	-999	None	None	Blank
MEAN_WIND_VECTOR_DIR_2M	0	360	-999	None	None	Blank
SDEV_WIND_DIR_2M	0	81	-999	None	None	Blank
CANOPY_TEMP_1	-27.2	-3.9	-999	None	None	Blank
CANOPY_TEMP_2	-27.4	-3	-999	None	None	Blank
TRUNK_TEMP_1	-27.2	-1.8	-999	None	None	Blank
TRUNK_TEMP_2	-27.4	-4.9	None	None	None	Blank
AIR_TEMP_2M	-29.5	-6.3	-999	None	None	Blank
SNOW_SURF_TEMP	-17.4	-8.3	-999	None	None	Blank
REL_HUM_2M	28	86.2	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	18-JUN-97	18-JUN-97	None	None	None	None

Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.
Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.

```
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits.  This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
                      determine the parameter value.  This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.
Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
-------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following are wrapped versions of data records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,MEAN_DOWN_THERMAL_RAD_1,
MEAN_DOWN_THERMAL_RAD_2,MEAN_WIND_SPEED_2M,MEAN_WIND_SPEED_VECTOR_MAG_2M,
MEAN_WIND_VECTOR_DIR_2M,SDEV_WIND_DIR_2M,CANOPY_TEMP_1,CANOPY_TEMP_2,
TRUNK_TEMP_1,TRUNK_TEMP_2,AIR_TEMP_2M,SNOW_SURF_TEMP,REL_HUM_2M,
CRTFCN_CODE,REVISION_DATE
'SSA-9OA-FLXTR','HYD03-SCM01',04-MAR-96,2010,226.4,227.0,.938,.907,34.25,14.55,,
,-21.7,-16.8,-17.9,-999.0,59.2,'CPI',18-JUN-97
'SSA-9OA-FLXTR','HYD03-SCM01',04-MAR-96,2011,226.3,226.9,.89,.831,42.95,20.8,,,-
22.0,-16.9,-18.1,-999.0,59.4,'CPI',18-JUN-97
```

8. Data Organization

8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is a day's worth of data for a given site.

8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae
Not applicable.

9.1.1 Derivation Techniques and Algorithms
Not applicable.

9.2 Data Processing Sequence
Not applicable.

9.2.1 Processing Steps
Not applicable.

9.2.2 Processing Changes
Not applicable.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
Infrared thermometer #3 did not provide reliable data when air temperatures were below -15 °C, so all the bad thermal data were replaced with -999. Reliable data from infrared radiometer #3 were obtained only when air temperatures were greater than -15 °C. Infrared thermometer #3 was used to collect trunk temperature at the SSA-OBS and snow surface temperature at the SSA-OA.

It is important to note that the wind direction sensor was oriented to true south during installation, except in 1996 when the sensor was oriented to magnetic south. A Brunton compass was used in the orientation of the sensor. This sensor is better oriented to the south because of a 5° "dead zone" between 355° and 360°.

Any wind speed data with a value less than 0.0 were changed to 0.

9.3.2 Calculated Variables
None.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
Assuming an operative instrument, the primary source of error for the wind direction sensor is in the initial installation and the ability of the installer to accurately orient the monitor.

10.2 Quality Assessment

10.2.1 Data Validation by Source
Wind, air temperature, and relative humidity data were compared with Saskatchewan Research Council (SRC) data measured above the canopy.

10.2.2 Confidence Level/Accuracy Judgment
Great care was taken to orient the wind monitor during installation. Quantification of the accuracy beyond the manufacturer's accuracy is difficult. The wind speed data are all below the threshold value of 1.0 m/s; therefore, the data are not absolute. These wind speed data are useful only for determining

the occurrence of wind events. Similarly, wind direction data are also useful only during the wind events because wind direction data under calm conditions are meaningless. Temperature and relative humidity data are as good as the accuracy of the instrument. Canopy, trunk, and snow surface temperature data quality are limited by the accuracy of the infrared thermometer.

10.2.3 Measurement Error for Parameters

Not available.

10.2.4 Additional Quality Assessments

Not available.

10.2.5 Data Verification by Data Center

Data that were loaded into the data tables were spot checked against the original ASCII data that were submitted to check for data loading errors.

11. Notes

11.1 Limitations of the Data

The wind speed data are all below the threshold value of 1.0 m/s; therefore, the data are not absolute. These wind speed data are useful only for determining the occurrence of wind events. Similarly, wind direction data are also useful only during the wind events because wind direction data under calm conditions are meaningless.

11.2 Known Problems with the Data

Infrared thermometer #3 did not provide reliable data when air temperatures were below -15 °C, so all the bad thermal data were replaced with -999. Reliable data from infrared radiometer #3 were obtained only when air temperatures were greater than -15 °C. Infrared thermometer #3 is the third one in the data field.

11.3 Usage Guidance

The wind speed data are all below the threshold value of 1.0 m/s; therefore, the data are not absolute. These wind speed data are useful only for determining the occurrence of wind events. Similarly, wind direction data are also useful only during the wind events because wind direction data under calm conditions are meaningless.

It is important to note that the wind direction sensor was oriented to true south during installation, except in 1996 when the sensor was oriented to magnetic south. A Brunton compass was used in the orientation of the sensor. This sensor is better oriented to the south because of a 5° "dead zone" between 355° and 360°.

11.4 Other Relevant Information

Not available.

12. Application of the Data Set

This data set can provide information on the timing and relative magnitude of wind events in the forest and an approximate direction of wind. The data set, in conjunction with data from the tower, also provides insight into the relationship between above-canopy and below-canopy meteorology.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

An undetermined spreadsheet program was used to organize the data.

14.2 Software Access

None given.

15. Data Access

The subcanopy meteorological measurement data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/ [Internet Link].

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products
None.

16.2 Film Products
None.

16.3 Other Products
These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation
Data logger and temp/RH probe: manual available from manufacturer/distributor: Campbell Scientific, Inc. 815 W. 1800 N. Logan, UT 84321-1784 (801) 753-2342

Infrared thermometer manual available from manufacturer: Everest Interscience, Inc. 1120 S. Raymond Fullerton, CA 92631 (800) 422-4342

Wind sensor: manual available from manufacturer: R.M. Young Company 2801 Aero-Park Drive Traverse City, MI 49684 (616) 946-3980

17.2 Journal Articles and Study Reports
Davis, R.E., C. Woodcock, and J.P. Hardy. 1996. Toward spatially distributed modeling of snow in the boreal forest. Eos Transactions, AGU 1995 Fall Meeting, Abstract, p. 218.

Davis, R.E., J.P. Hardy, W. Ni, C. Woodcock, J.C. McKenzie, R. Jordan, and X. Li. 1997. Variation of snow cover ablation in the boreal forest: A sensitivity study on the effects of conifer canopy. Journal of Geophysical Research. 102(D24):29,389-29,395.

Hardy, J.P., R.E. Davis, and J.C. McKenzie. 1995. Snow Distribution Around Trees: Incorporation of snow interception patterns into spatially distributed snow models. Eos Transactions, AGU 1995 Fall Meeting, Abstract, p. 202.

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Hardy, J.P., R.E. Davis, R. Jordan, W. Ni and C. Woodcock, 1998. Snow ablation modelling in a mature aspen stand of the boreal forest. Hydrological Processes, 12 (10/11), p. 1763-1778.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Ni, W., X. Li, C.E. Woodstock, J.L. Roujean, and R.E. Davis. 1997. Transmission of solar radiation in boreal conifer forests: Measurements and models. Journal of Geophysical Research.

102(D24):29,555-29,566.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

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ASCII    - American Standard Code for Information Interchange
BOREAS   - BOReal Ecosystem-Atmosphere Study
BORIS    - BOREAS Information System
CD-ROM   - Compact Disk-Read-Only Memory
CGR      - Certified by Group
CPI      - Certified by Principal Investigator
CPI-???  - CPI but questionable
CRREL    - Cold Regions Research and Engineering Laboratory
DAAC     - Distributed Active Archive Center
EOS      - Earth Observing System
EOSDIS   - EOS Data and Information System
FFC-W    - BOREAS Focused Field Campaign - Winter
FOV      - Field of View
GIS      - Geographic Information System
GMT      - Greenwich Mean Time
GSFC     - Goddard Space Flight Center
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HTML - Hyper-Text Markup Language
HYD - Hydrology
IR - Infrared
NAD83 - North American Datum of 1983
NASA - National Aeronautics and Space Administration
NSA - Northern Study Area
OA - Old Aspen
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PIR - Precision Infrared Radiometer
PRE - Preliminary
RH - relative humidity
SRC - Saskatchewan Research Council
SSA - Southern Study Area
temp - Temperature
TF - Tower Flux
URL - Uniform Resource Locator

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Davis, R.E., J. P. Hardy, W. Ni, C. Woodcock, C.J. McKenzie, R. Jordan and X. Li, 1997. Variation of snow cover ablation in the boreal forest: A sensitivity study on the effects of conifer canopy. J. of Geophys. Res., 102 ($N_2$4), 29,389-29,396, December 26, 1997.

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Hardy, J.P., R.E. Davis, R. Jordan, X. Li, C. Woodcock, W. Ni and J.C. McKenzie, 1997. Snow ablation modeling at the stand scale in a boreal jack pine forest. , J. of Geophys. Res., 102 (N24), 29,397-29,406, December 26, 1997 .

If using data from the BOREAS CD-ROM series, also reference the data as:

R.E. Davis, "Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS HYD-3 team collected several data sets related to the hydrology of forested areas. This data set includes measurements of wind speed and direction; air temperature; relative humidity; and canopy, trunk, and snow surface temperatures within three forest types. The data were collected in the SSA-OJP (1994) and SSA-OBS and SSA-OA (1996). Measurements were taken for 3 days in 1994 and 4 days at each site in 1996. These measurements were intended to be short term to allow the relationship between subcanopy measurements and those collected above the forest canopy to be determined. The subcanopy estimates of wind speed were used in a snow melt model to help predict the timing of snow ablation. The data are available in tabular ASCII files.

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